In the Specification:

On page 1, after the title insert the following:

RELATED APPLICATIONS

This is a U.S. national stage of application No. PCT/DE2003/002728, filed on 13 August 2003.

This patent application claims the priority of German patent application no. 102 41 192.1, filed 05 September 2002, the disclosure content of which is hereby incorporated by reference.

FIELD OF THE INVENTION

On page 1, amend the paragraph beginning on line 6, as follows:

The invention relates to an optically pumped radiation-emitting semiconductor device ~~in accordance with the preamble of patent claim 1~~ and to a method for fabricating it ~~in accordance with the preamble of patent claim 19 or 25~~.

On page 1, before line 12, insert the following heading:

BACKGROUND OF THE INVENTION

On page 1, amend the paragraph beginning on line 12 as follows:

An optically pumped radiation-emitting semiconductor device is known, for example, from published U.S. patent application no. 2003/0001328 ~~document DE 100 26 734.3~~, the content of which is incorporated by reference in the present description. The above document describes an optically pumped surface-emitting semiconductor laser device having a radiation-

generating quantum well structure and a pump radiation source, for example a pump laser, for optically pumping the quantum well structure. The quantum well structure and the pump radiation source are grown epitaxially on a common substrate.

On page 2, before line 3, insert the following heading:

SUMMARY OF THE INVENTION

On page 2, amend the paragraph beginning on line 3 as follows:

~~It is an~~ One object of the present invention is to provide an optically pumped radiation-emitting semiconductor device having a quantum well structure and a pump radiation source, which are monolithically integrated, with improved efficiency[[. In particular]], such as by reducing the losses that occur when introducing the pump radiation into the quantum well structure ~~are to be reduced~~.

A further object of the invention is to provide a method for fabricating this semiconductor device.

On page 2, delete the paragraph beginning on line 13 in its entirety.

On page 2, amend the paragraph beginning on line 19 as follows:

~~The invention provides for the formation of~~ These and other objects are attained in accordance with one aspect of the present invention directed to an optically pumped radiation-emitting semiconductor device having a semiconductor body which includes at least one pump radiation source and a surface-emitting quantum well structure, the pump radiation source and

the quantum well structure being monolithically integrated, and the pump radiation source generating pump radiation for optically pumping the quantum well structure. A recess for introducing the pump radiation into the quantum well structure is formed in the semiconductor body between the pump radiation source and the quantum well structure.

~~The~~ In accordance with an embodiment of the invention, the recess is ~~in particular~~ arranged in such a way that when it is being formed the grow-in region between the quantum well structure and the pump radiation source is removed. It has been found that the losses involved in introducing the pump radiation are advantageously reduced by means of a recess formed in a defined way of this type compared to the losses involved in introducing the pump radiation through the grow-in region described above.

On page 3, amend the paragraph beginning on lines 16 and 26 as follows:

In ~~an advantageous~~ one refinement of the invention, the recess is in the form of a trench, the trench running perpendicular or obliquely with respect to a direction of propagation of the pump radiation, ~~preferably~~ such as with respect to the main direction of emission of the pump radiation source. A recess in trench form is relatively space-saving and can be formed with little technical outlay during fabrication, for example, as an etched trench.

~~It is preferable for the~~ The recess ~~to~~ can have a first side face and an opposite, ~~preferably~~ parallel second side face, the pump radiation generated by the pump radiation source first of all being introduced into the recess through the first side face and then being introduced into the quantum well structure through the opposite second side face. The removal of the grow-in region during formation of the recess with defined side faces advantageously reduces the losses involved in introducing the pump radiation into the quantum well structure.

On page 3, amend the paragraph beginning on line 38 through page 4, line 13, as follows:

To avoid reflections at the side faces of the recess, ~~it is also advantageous for~~ the recess ~~to~~ can be filled with a dielectric or a semiconductor material. This reduces the sudden change in refractive index at the side faces, and consequently reduces the reflection of the pump radiation at the side faces, thereby further increasing the amount of pump radiation which is introduced into the quantum well structure. ~~It is preferable for the~~ The material for the filling of the recess ~~to~~ can be selected in such a way that the refractive index is as far as possible similar or even equal to the refractive index of the adjoining semiconductor material, in particular in the region of the pump radiation source which carries pump radiation.

On page 4, amend the paragraph beginning on line 22 as follows:

To reduce the reflection losses at the side faces, in a ~~preferred~~ refinement of the invention, the side faces are arranged in such a way that they include an angle equal to the Brewster angle with a main emission direction of the pump radiation source. The Brewster angle α_B is given by the following relationship

$$\tan \alpha_B = n_A / n_P$$

in which n_A denotes the refractive index of the material located in the recess - which may also be air or another suitable gas - and n_P denotes the refractive index of the adjoining semiconductor material of the pump radiation source within which the pump radiation propagates. Arranging the side faces at the Brewster angle with respect to the main emission direction of the pump radiation source minimizes the reflection losses for those components of the pump radiation which are polarized parallel to the plane of incidence (with respect to the side face of the recess).

On page 5, amend the paragraphs beginning on lines 6 and 18 as follows:

In an aspect of the invention, it is preferable for the pump radiation source to be designed as a laser, in particular as an edge-emitting laser or as a ring laser. This results in strong focusing of the pump radiation with an accurately defined direction of propagation and a narrow spectral distribution. In this way, the pump radiation can be optimally designed for optical pumping of the quantum well structure and can be accurately radiated into the quantum well structure. Furthermore, the quantum well structure may also be arranged within a resonator of the pump laser.

In an aspect of the invention, the pump radiation is preferably introduced in the lateral direction into the quantum well structure, which means that the radiation emission of the quantum well structure takes place substantially vertically, i.e. perpendicular to the direction of propagation of pump radiation. Furthermore, the semiconductor device may be designed as a vertically emitting laser, for example as a VCSEL (Vertical Cavity Surface Emitting Laser) or as a disc laser.

On page 5, amend the paragraph beginning on line 28 through page 6, line 5 as follows:

~~In a method according to the invention for fabricating an optically pumped radiation-emitting semiconductor device, first of all a substrate is provided for the semiconductor body to grow on, then a plurality of semiconductor layers, which inter alia form the quantum well structure, are epitaxially grown on this substrate. Then, these semiconductor layers are partially removed and the pump radiation sources grown on the regions uncovered in this way, so that the pump radiation source laterally adjoins the quantum well structure.~~ Another aspect of the invention is directed to a method for fabricating an optically pumped semiconductor device

having a semiconductor body which includes a surface-emitting quantum well structure and at least one pump radiation source which generates pump radiation for optically pumping the quantum well structure, the pump radiation source and the quantum well structure being monolithically integrated. A substrate is provided, and a plurality of semiconductor layers are epitaxially grown on the substrate, which layers include the quantum well structure. The semiconductor layers are partially removed, and the pump radiation source is epitaxially grown in the region uncovered by the removal step so that the pump radiation source adjoins the quantum well structure. A recess for introducing the pump radiation into the quantum well structure is formed between the pump radiation source and the quantum well structure.

~~The~~ In the absence of the present invention, the semiconductor layers of the pump radiation source can grow laterally together with the semiconductor layers of the quantum well structure, so that a grow-in region with a relatively strongly disrupted crystal structure is formed between the pump radiation source and the quantum well structure.

On page 6, amend the paragraph beginning on line 16 as follows:

~~It is preferable for the~~ The recess ~~to~~ can be etched into the semiconductor body. Both wet-chemical processes and dry-chemical processes, such as for example RIBE processes or CAIBE processes are suitable for this purpose. As has already been described, it is advantageous for the recess to be formed as an etched trench.

On page 6, delete the paragraphs beginning on lines 24 and 31 in their entirety and add the following:

Another aspect of the invention is directed to a method for fabricating an optically pumped semiconductor device having a semiconductor body which includes a surface-emitting quantum well structure and at least one pump radiation source which generates pump radiation for optically pumping the quantum well structure, the pump radiation source and the quantum well structure being monolithically integrated. A substrate is provided, and a plurality of semiconductor layers are epitaxially grown on the substrate, which layers include the pump radiation source and form the quantum well structure. A window is formed in the plurality of semiconductor layers for the quantum well structure, and the quantum well structure is expitaxially grown in the window so that the pump radiation source adjoins the quantum well structure. A recess for introducing the pump radiation into the quantum well structure is formed between the pump radiation source and the quantum well structure.

On page 7, amend the paragraph beginning on line 1, as follows:

In the fabrication method, ~~it is preferable for~~ the recess ~~to~~ can be filled with a semiconductor material or a dielectric in order to reduce the sudden change in refractive index between recess and adjoining semiconductor material and the associated reflection losses. By way of example, the recess may be filled with silicone.

On page 7, delete the paragraph beginning on line 16 in its entirety.

On page 7, before line 21, insert the following heading:

BRIEF DESCRIPTION OF THE DRAWINGS

On page 8, before line 8, insert the following heading:

DETAILED DESCRIPTION OF THE DRAWINGS

On page 8, amend the paragraph beginning on line 12 as follows:

Figure 1a illustrates a sectional view through an optically pumped radiation-emitting semiconductor device, and Figure 1b shows the associated plan view. The section plane associated with Figure 1a runs on line A-A in Figure 1b. The semiconductor device has a semiconductor body which is arranged on a substrate 1 and comprises a surface-emitting region 15 and two pump radiation sources 20. A surface-emitting quantum well structure 11 [[, which]] in operation is optically pumped by the pump radiation sources 20 and generates radiation 5 that is emitted perpendicular to the surface 4 of the substrate 1 or the boundary surface 8 between the semiconductor body and the substrate 1[[,]] .The quantum well structure 11 is formed in the surface-emitting region 15.

On page 14, amend the paragraph beginning on line 16 as follows:

The edge-emitting laser structures may also be arranged in a common resonator delimited by the two mirror layers 31 or side faces 16, so that the quantum well structure is also located within this resonator. Alternatively, the outer side faces 26 ~~16~~ of the recess 10, as seen from the quantum well structure 11, together with the associated mirror surface 31 or side face 16 ~~27~~, may in each case form a resonator for the edge-emitting semiconductor lasers, so that the quantum

well structure 11 is arranged between these two resonators. A further alternative is for the pump radiation source to be designed as a ring laser and for the quantum well structure to be arranged within the ring resonator.

On page 15, amend the paragraph beginning on line 5 as follows:

On the opposite surface 4 of the substrate 1 from the quantum well structure 11 and the pump radiation sources 20, an n-type contact layer 9, for example a contact metallization is shaped to form an exit window 14. ~~which is recessed in the surface-emitting region 15, is applied in a corresponding way to the p-type contact layer 32.~~ This ~~recess forms an~~ exit window 14 is for the radiation 5 generated by the quantum well structure 11. Contact layer 9 is applied to correspond with p-type contact layer 32 to provide electrical contacts for the device, and in particular for pump radiation sources 20. It is preferable for the surface 4 of the substrate to be provided with an antireflection coating within the exit window 14, in order to reduce back-reflections of the radiation 5 emitted by the quantum well structure 11. Of course, the mention of n-type and p-type contacts refers to the corresponding semiconductor material, not necessarily to the contact layer itself having such conductivity type.

On page 20, delete the paragraph beginning on line 22 in its entirety and insert the following:

The scope of protection of the invention is not limited to the examples given hereinabove. The invention is embodied in each novel characteristic and each combination of characteristics, which includes every combination of any features which are stated in the claims, even if this combination of features is not explicitly stated in the claims.